CLAIMS

We claim:

1. A high-impedance optical electrode used for measuring bio-potentials comprising:
   a) a light source;
   b) an electro-optic modulator:
      (1) receiving light from said light source;
      (2) modulating said light in response to a bio-potential; and
      (3) providing a modulated light output proportional to said bio-potential.

2. The high-impedance optical electrode used for measuring bio-potentials according to claim 1 further comprising a photodetector for receiving and converting said modulated light output from said electro-optic modulator to an electrical signal.

3. The high-impedance optical electrode used for measuring bio-potentials according to claim 2 further comprising electronic circuitry for providing an electronic output signal.

4. The high-impedance optical electrode used for measuring bio-potentials according to claim 1 further comprising a pilot tone generated by said electronic circuitry and superimposed on said bio-potential.

5. The high-impedance optical electrode used for measuring bio-potentials according to claim 1 further comprising an optical splitter for splitting said light from said light source into at least a second light portion.

6. The high-impedance optical electrode used for measuring bio-potentials according to claim 5 wherein said second light portion is received by a second electro-optical modulator.

7. The high-impedance optical electrode used for measuring bio-potentials according to claim 5 wherein said second light portion is used as an optical reference signal.

8. The high-impedance optical electrode used for measuring bio-potentials according to claim 1 further comprising an optical phase-shift modulator.

9. A high impedance optical electrode for measuring bio-potentials comprising:

a) a light source;

b) a bio-potential;

c) an electro-optic modulator;

(1) receiving light from said light source;

(2) modulating said light in response to a bio-potential; and

(3) providing a modulated light output; and

d) a photodetector for receiving and converting said modulated light output from said electro-optic modulator into an electrical output.

10. The high impedance optical electrode according to claim 9 wherein said electrical output is a voltage.

11. The high impedance optical electrode according to claim 9 wherein said light source is a laser diode.

12. The high impedance optical electrode according to claim 11 wherein said laser diode is a highly coherent laser diode.

13. The high impedance optical electrode according to claim 11 wherein said laser diode is a low coherent laser diode.

14. The high impedance optical electrode for measuring bio-potentials according to claim 9 wherein said light source is a distributed feedback laser .

15. The high impedance optical electrode for measuring bio-potentials according to claim 9 wherein said light source is a Fabry-Perot laser.

16. The high impedance optical electrode for measuring bio-potentials according to claim 9 wherein said light source is a vertical cavity surface-emitting laser.

17. The high impedance optical electrode for measuring bio-potentials according to claim 9 wherein said light source is connected to said electro-optic modulator with an optical fiber.

18. The high impedance optical electrode for measuring bio-potentials according to claim 9 wherein said electro-optic modulator is connected to said photodetector with an optical fiber.

19 The high impedance optical electrode for measuring bio-potentials according to claim 17 wherein said electro-optic modulator is connected to said photodetector with an optical fiber.

20. The high impedance optical electrode for measuring bio-potentials according to claim 9 wherein at least one end of said electro-optic modulator connected to at least one member of a group of members consisting of: an optical fiber, said light source, and said photodetector, is formed at an angle to vertical.

Fig. 4
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21. The high impedance optical electrode for measuring bio-potentials according to claim 9 wherein at least one end of said electro-optic modulator is connected to an optical fiber with an optical carrier.

22. The high impedance optical electrode for measuring bio-potentials according to claim 21 wherein an end of said optical carrier connected to said electro-optic modulator is formed at an angle to vertical.

23. The high impedance optical electrode for measuring bio-potentials according to claim 9 wherein at least said electro-optic modulator is enclosed in a housing.

24. The high impedance optical electrode for measuring bio-potentials according to claim 23 wherein said housing is hermetically sealed.

25 The high impedance optical electrode for measuring bio-potentials according to claim 23 wherein said housing is at least partially covered with electro-magnetic shielding.

26. The high impedance optical electrode for measuring bio-potentials according to claim 25 wherein said electro-magnetic shielding is a conductive paint.

27. The high impedance optical electrode for measuring bio-potentials according to claim 23 wherein said housing provides a ground return.

28. The high impedance optical electrode for measuring bio-potentials according to claim 9 wherein said electro-optic modulator is a Mach- Zehnder interferometer.

29. The high impedance optical electrode for measuring bio-potentials according to claim 28 wherein said Mach-Zehnder interferometer operates in a linear region.

30. The high impedance optical electrode for measuring bio-potentials according to claim 28 with said Mach-Zehnder interferometer comprising:

a) a substrate having formed therein:

(1) a light input wave-guide receiving light from said light source;

(2) a splitter connected to said light input wave-guide;

(3) a first leg light wave-guide connected to said splitter;

(4) a second leg light wave-guide connected to said splitter;

(5) a combiner connected for receiving light from said first leg light wave-guide and said second leg light wave-guide; and

(6) a light output wave-guide connected to said combiner.

31. The high impedance optical electrode for measuring bio-potentials according to claim 30 wherein said substrate is crystalline.

32. The high impedance optical electrode for measuring bio-potentials according to claim 30 wherein said substrate is crystalline.

33. The high impedance optical electrode for measuring bio-potentials according to claim 30 wherein said crystalline substrate comprises $LiNbO_3$.

34. The high impedance optical electrode for measuring bio-potentials according to claim 30 further comprising:

a) a bio-potential plate mounted on said substrate between said first leg light wave-guide and said second light wave-guide;

b) a first grounding plate mounted on said substrate on a side of said first leg light wave-guide opposite said bio-potential plate; and

c) a second grounding plate mounted on said substrate on a side of said second leg light wave-guide opposite said bio-potential plate.

35. The high impedance optical electrode for measuring bio-potentials according to claim 34 wherein said grounding plates are connected to a ground return provided by a housing.

36 The high impedance optical electrode for measuring bio-potentials according to claim 34 further comprising a pick-up pad electrically connected to said bio-potential plate.

37 The high impedance optical electrode for measuring bio-potentials according to claim 36 further comprising of a shunt resistor connected to said bio-potential plate and said grounding plate.

38. The high impedance optical electrode for measuring bio-potentials according to claim 30 wherein a spatial filter is mounted to an end of said substrate.

39 The high impedance optical electrode for measuring bio-potentials according to claim 30 further comprising a strap for securing said electro-optic modulator to a patient.

40 The high impedance optical electrode for measuring bio-potentials according to claim 30 further comprising a helmet for positioning at lease one of said electro-optic modulator on a patient.

41. The high impedance optical electrode for measuring bio-potentials according to claim 40 wherein said helmet provides a ground return for said electro-optic modulator.

42. The high impedance optical electrode for measuring bio-potentials according to claim 9 further comprising a bio-potential plate for receiving said bio-potential and modulating said light in response thereto.

43. The high impedance optical electrode for measuring bio-potentials according to claim 42 wherein said bio-potential plate is electrically connected to a pick-up pad for acquiring said bio-potential.

44. The high impedance optical electrode for measuring bio-potentials according to claim 43 wherein said pick-up pad is used without conductive ointments.

45. The high impedance optical electrode for measuring bio-potentials according to claim 43 wherein said pick-up pad has an irregular surface.

46. The high impedance optical electrode for measuring bio-potentials according to claim 43 with said pick-up pad comprising an electrically conducting disk.

47. The high impedance optical electrode for measuring bio-potentials according to claim 43 wherein said pick-up pad is mounted to a housing for said electro-optic modulator.

48. The high impedance optical electrode for measuring bio-potentials according to claim 42 wherein said bio-potential plate receives said bio-potential through clothing.

49. The high impedance optical electrode for measuring bio-potentials according to claim 42 wherein said bio-potential plate receives said bio-potential as a result of capacitive coupling.

50. The high impedance optical electrode for measuring bio-potentials according to claim 9 further comprising of an optical power splitter for receiving light from said light source and providing said light to at least two light receiving devices.

51 The high impedance optical electrode for measuring bio-potentials according to claim 50 wherein one of said light-receiving devices is a second photodetector.

52. The high impedance optical electrode for measuring bio-potentials according to claim 51 wherein said second photodetector is a reference photodetector.

53. The high impedance optical electrode for measuring bio-potentials according to claim 50 wherein one of said light receiving devices is a second electro-optic modulator.

54. The high impedance optical electrode for measuring bio-potentials according to claim 50 wherein said optical splitter comprises an N-splitter.

55. The high impedance optical electrode for measuring bio-potentials according to claim 50 wherein said optical splitter comprises an X:Y splitter.

56. The high impedance optical electrode for measuring bio-potentials according to claim 9 further comprising a phase modulator receiving light from one of the light source and said electro-optic modulator.

57. The high impedance optical electrode for measuring bio-potentials according to claim 56 with said phase modulator comprising a piezo-electric substrate having formed therein a light waveguide with a hot electrode and a ground electrode mounted opposite each other on each side of said waveguide.

58. The high impedance optical electrode for measuring bio-potentials according to claim 57 further comprising a frequency generator for imposing a potential on said hot electrode with a frequency higher than a frequency range of said bio-potential.

59. The high impedance optical electrode for measuring bio-potentials according to claim 9 further comprising electronic circuitry for processing said electrical output from said photodetector.

60. The high impedance optical electrode for measuring bio-potentials according to claim 59 with said electronic circuitry comprising post photodetector processing.

61. The high impedance optical electrode for measuring bio-potentials according to claim 59 with said electronic circuitry comprising DC transient suppression circuitry.

62. The high impedance optical electrode for measuring bio-potentials according to claim 59 with said electronic circuitry comprising amplification circuitry.

63. The high impedance optical electrode for measuring bio-potentials according to claim 59 with said electronic circuitry comprising filtering circuitry.

64. The high impedance optical electrode for measuring bio-potentials according to claim 59 with said electronic circuitry comprising pilot tone generation circuitry.

65. The high impedance optical electrode for measuring bio-potentials according to claim 59 wherein a pilot tone from said pilot tone generation circuitry is superimposed on said bio-potential at a frequency outside of the frequency range of said bio-potential.

66. The high impedance optical electrode for measuring bio-potentials according to claim 65 wherein said pilot tone is applied directly to a patient.